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ABSTRACT

This programmed instruction booklet is an interim version of instructional materials being developed by Harvard Project Physics. It is the first in a series of three booklets on vectors and covers the definitions of vectors and scalars, drawing vector quantities to scale, and negative vectors. For others in this series, see SE 015 550 and SE 015 551. (DT)

Project Physics **Programmed Instruction**

Vectors 1

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Authorized Interim Version [redacted] 1968-69

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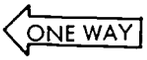
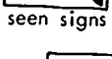
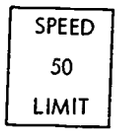
Vectors 1 The Concept of Vectors



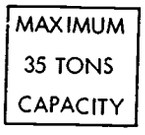
You are familiar with signs such as



that indicate a direction. You have also seen signs which give a magnitude such as



OR



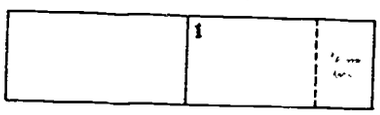
This program is about quantities that have both a direction and a numerical value. These are called vectors and they are very important in physics

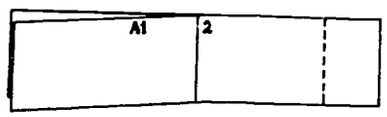
You are already familiar with some examples of vectors. This part of the program will start with these examples.

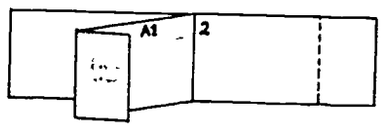
INSTRUCTIONS

1. Frames: Each frame contains a question. Answer the question by writing in the blank space next to the frame. Frames are numbered 1, 2, 3,...

2. Answer Blocks: To find an answer to a frame, turn the page. Answer blocks are numbered A1, A2, A3, ... This booklet is designed so that you can compare your answer with the given answer by folding back the page, like this:







3. Always write your answer before you look at the given answer.

4. If you get the right answers to the sample questions, you do not have to complete the program.

Sample Question A

Answer Space

Complete this sentence if you can:

A scalar quantity can be expressed by (i) _____, but a vector quantity must be expressed by both (ii) _____.

Answer to A

(i) a number (with or without units)

(ii) a number (with or without units) and a direction.

Sample Question B

Answer Space

It is important to be able to distinguish between vector and scalar quantities in equations.

(i) List all of the vector quantities in the equation

$$\vec{T} = m\vec{a} + 6\vec{P}.$$

(ii) List all of the scalar quantities in the same equation.

Answer to 3

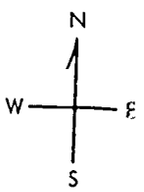
(i) $\vec{T}$, $\vec{a}$, and $\vec{P}$

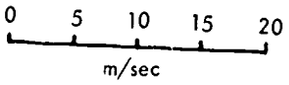
(ii) m and 6

Sample Question C

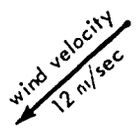
Answer Space

Suppose the wind is blowing from the northeast at 12 m/sec. Draw an arrow that represents this wind velocity to the scale given.



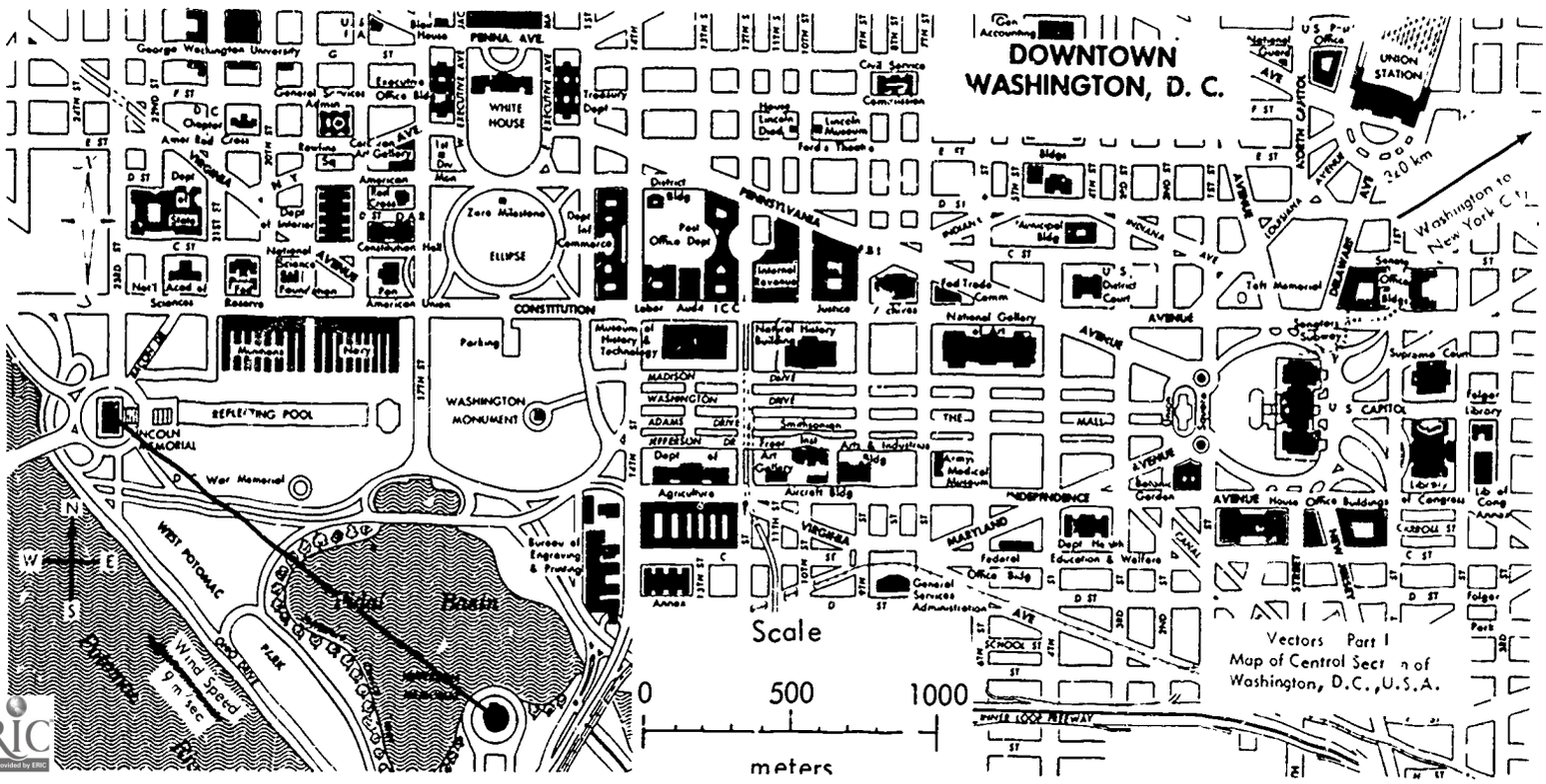


Answer to C



If you answered all 3 sample questions correctly, you are ready for the Vectars 2 program.

If not, begin with question 1 on the next page.



1

Questions 1 through 15 require a map of Washington, D.C., which is provided with the booklet.

Find the location of the Lincoln Memorial and the Jefferson Memorial on the map of Washington, D.C. A straight line is shown between the memorials. According to the scale on the map, the distance between the Lincoln and Jefferson Memorials is _____ meters.

(Hint: One way to use the scale on the map is to copy it off the edge of a piece of paper which can be placed along any line you wish to measure.)

A1

about 1700 meters, measuring
center to center

2

From the compass directions on the map we can see that the Jefferson Memorial is located 1700 meters _____ of the Lincoln Memorial.

3

Locate the White House, and find the distance and direction of the White House from the Jefferson Memorial.

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approximately 2100 meters to the north

One of the important concepts of physics is that of displacement, which is the straight line distance between the initial and final locations of an object. Use the map of Washington, D.C., to answer the following questions:

(i) What building will you reach if you start at the Washington Monument and travel 2600 meters due east?

(ii) What was your displacement?

A4

(i) the U.S. capitol

(ii) 2600 m east from the Washington Monument

(i) What would be your displacement if you traveled from the Capitol to the White House?

(ii) What is the displacement if something is moved from the White House to the Washington Monument?

(i) 2900 m, approximately northwest (actually 290° from north)

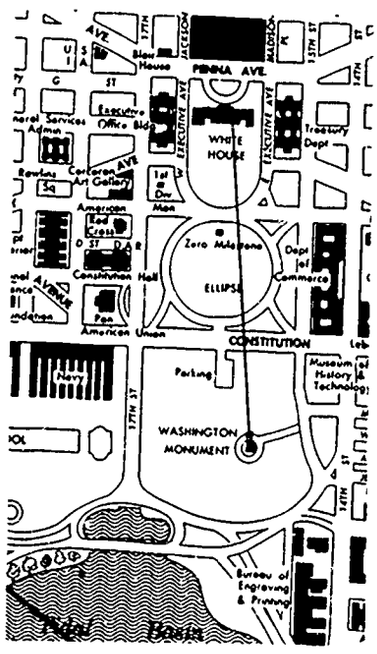
(ii) 1100 m south (actually slightly east of south)

6

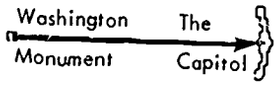
A displacement can be represented by an arrow on a map. The length of the arrow represents a scale drawing of the actual displacement.

(i) What displacement is shown?

(ii) Draw the arrow on your map of Washington that can represent the displacement from the Washington Monument to the Capitol.



(i) White House to Washington Monument (1100 m south)

(ii) 

(i) Draw an arraw on the map to represent the displacement of a person who hos wolked from the Washingtan Monument to the Jeffersor Memorial.

(ii) Draw on the map the shortest path for walking on dry ground from the Washington Monument to the Jefferson Memorial.

(iii) Daes the choice of path change the displacement?

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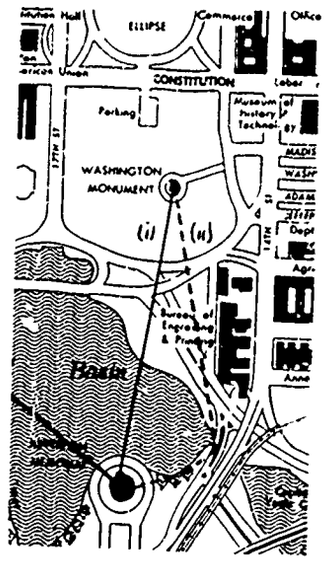


(iii) no (it changes the path length, but not the displacement, which is defined as the straight-line distance.)

8

On the map of Washington, D.C., there is an arrow which indicates that the displacement of New York City from Washington is _____ .
distance? direction?

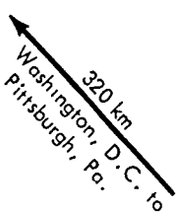
A8

320 km northeast

Note that the distance scale at the bottom of the map is for measurements inside Washington, and the displacement to more remote places such as New York City is represented with another scale. It is not essential that the arrow representing a displacement vector be drawn to the same scale as the map.

Pittsburgh, Pennsylvania, is approximately 320 kilometers to the northwest of Washington. Draw near the top of the map the arrow by which you can represent this displacement.

(Use the same scale as the arrow showing the displacement of New York City.)



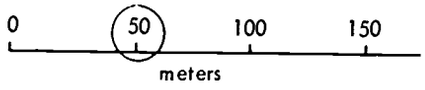
Quantities that have both magnitude and direction are called vectors.

Quantities that have a magnitude but no direction are called scalars.

Is the displacement shown below a scalar or a vector?

vector

Quantities that have only a magnitude are called scalars. Those quantities that have both magnitude and direction are called vectors.



Is the position of the 50 meter mark on the scale a vector or a scalar?

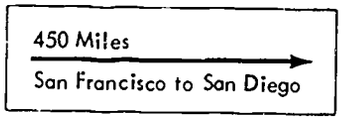
scalar

A scalar quantity can be expressed by a single number (with or without units), but a vector must have both _____ .

magnitude and direction

Are the following pictures representations of vectors, of scalars, or of neither?

(i)



(ii)

(i) vector (a displacement)

(ii) neither (only direction)

On the map of Washington, D.C., there is an arrow representing the wind velocity. The arrow indicates that the wind is blowing from the (i) _____ at a speed of (ii) _____.

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(i) southeast

(ii) 9 m/sec (about 20 miles/hr)

The speed and direction of the wind is a vector quantity, and therefore it can be represented by an arrow drawn to scale. Suppose the wind changed and is now coming from the west at 18 m/sec.

On the map, draw the new wind direction, and indicate the new wind speed by making the arrow of the proper length (using the other wind arrow as a guide).

wind speed = 18 m/sec

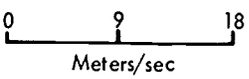
(This is twice as long as the length shown for a wind speed of 9 m/sec.)

(i) Use the wind vector shown on the map to draw a scale for the wind speed.

(ii) What is the length of the arrow needed to represent a wind speed of 27 meters/sec?

A16

(i) Scale



(ii) three times the length for 9m/sec

Whenever we encounter a physical quantity--such as speed, force, energy, or whatever--it is useful for us to know whether or not it involves direction. Those quantities that involve direction as well as magnitude are called

(i) _____.

(ii) Does the pull each team exerts on the rope in the tug-of-war involve a direction?

Photo G Kew, LIFE MAGAZINE, © Time Inc

A17

(i) vectors

(ii) yes

18. When we encounter a physical quantity that is a scalar we mean it has no

(i)_____ .

(ii) Is the diameter of the water wheel shown here a vector or a scalar?

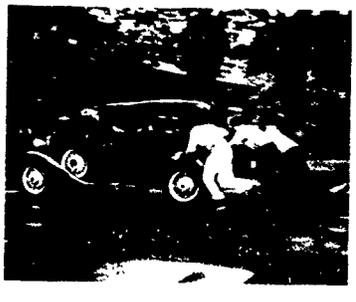
Photo C. W. Kirklond,
LIFE MAGAZINE, © Time Inc.

(i) direction

(ii) scalar

Four boys are shown pushing a car. The force each boy exerts on the car is a

(i) _____ quantity, and the number of boys pushing the car is a (ii) _____ quantity.



(i) vector

(ii) scalor

When writing one usually draws a small arrow over the symbol used for vector quantities. For example, in the equation

$$\vec{F} = m\,\vec{a},$$

$\vec{F}$ represents a vector quantity, the force, and $\vec{a}$ represents an acceleration in the same direction as $\vec{F}$. The letter m represents a scalar, mass.

(i) List all vector quantities in the equation

$$\vec{T} = m\,\vec{a} + 6\,\vec{N}$$

(ii) List all of the scalar quantities in the same equation.

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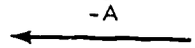
(i) $\vec{T}$, $\vec{a}$, $\vec{N}$
(Did you put the arrows over the symbols?)

(ii) m, 6

The negative of a vector quantity is represented by an arrow in the reverse direction. For example if $\vec{A}$ is represented by 

than $-\vec{A}$ is represented by 

If $\vec{B}$ is 

, draw $-\vec{B}$.

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22

If $-\vec{C}$ is  give a full label to: 

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A22

"C"

This ends Vectors 1.

You have learned to distinguish between vectors and scalars. You have drawn vector quantities to scale, and you have learned that a negative vector is in the opposite direction from the corresponding positive vector.

You are now ready to learn to add vector quantities. See the program booklet Vectors 2.